# Energy Generation from Biomass

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***Abstract*:** *Energy is highly essential for human survival and development of almost nine billion population world wide . It is generally generated by using fossil fuels, coal and other conventional sources like wind, hydro, solar, tyndall and others. Biomass seems to be one of the cheapest available renewable energy sources for power generation, cooking, lighting, communication and other routine requirements. Renewable energy from photovoltaics, wind turbines and small hydro plants is highly suitable for off-grid electricity supply. Application of biomass as a sustainable electricity source seems to be highly promising ad challenging. Biomass can be combusted, gasified, biologically digested, fermented, or converted to liquid fuels propelling a generator in order to generate electricity. Conversion from biomass to electricity is a low-carbon process as the resulting CO2 is captured by plant regrowth. In contrast with solar PV or wind power, biomass power technology can generate electricity on demand at any time, provided a sufficient supply of biomass stocks is assured. Many agricultural and forest product residues can provide feedstock for energy conversion without increasing land requirements. Local farmers can generate additional income by providing biomass fuels for small local power plants. Inspite of its benefit, there has been little experience of implementing small electricity-generating biomass plants in off-grid areas of developing countries. The current work is an attempt to review various options for power generation and compare their technoeconomic feasibility.*

***Keywords:*** *Biomass, renewable energy.*

## 1. Introduction

Exploding population and rapid industrialization has created a huge demand for energy supply all over world. These energies are mainly derived from petroleum, natural gas, coal, hydro and nuclear [Kulkarni, M.G. and A.K. Dalai, 2006.]. Petroleum based fuels have lots of disadvantage like, atmospheric pollution, greenhouse gas (GHG) and other air contaminants like NOx, SOx, CO, $CO_2$ (global warmimg), $H_2S$, inert gases, suspended particles, particulate matter and volatile organic compounds and many more [Klass, L.D., 1998]. Biomass is an alternative and renewable resource. It is widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. Biomass most often refers to lignocellulosic biomass and [Kulkarni, M.G. and A.K. Dalai, 2006.] important tool for mitigating greenhouse gas emissions. It is an important substitute of costly fossil fuels [Goldemberg, J., 2000;]. Its use at large-scale may contribute to sustainable development on several fronts, environmentally, socially and economic [Turkenburg, W.C., 2000]. It fixes $CO_2$ in the atmosphere through photosynthesis. Its combustion has no impact on the $CO_2$ balance in the atmosphere.

Among biomass, algae (macro and microalgae) usually have a higher photosynthetic efficiency than other biomass [Shay, E.G., 1993.]. Algae are the highest yielding feedstock for biodiesel. It can produce up to 250 times the amount of oil per acre as soybeans. Algae produce 7 to 31 time greater oil than palm oil. Microalgae are an organism capable of photosynthesis that is less than 2 mm in diameter. Microalgae has much more oil and it is much faster and easier to grow [7].

Renewable power generation provides 18% of total energy generation worldwide. About 32% of the total primary energy use in the country is still derived from biomass. More than 70% of the country's population depends upon it for its energy needs. Currently about 90% of all the bioenergy consumption is in the traditional use. Woody biomass is the source of over 10% of all energy supplied annually. Overall, woody biomass provides about 90% of the primary energy annually sourced from all forms of biomass. The estimated biomass

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production in the world is 104.9 petagrams ($104.9 \times 10^{15}$ g – about $10^5$ billion metric tons) of carbon per year, about half in the ocean and half on land.

## 1.1. Background

According to the definition given by Directive 2009/28/CE, biomass is "the fraction of products, waste and residues from biological origin, from agriculture, forestry and related industries including fisheries and aquaculture that has been biodegraded". Biomass is fundamentally different from carbon free energy sources like wind, water etc. Biomass gets its energy from the sun via a process called photosynthesis. Sunlight gives plants the energy they need to convert water and carbon dioxide into oxygen and sugars. These sugars, called carbohydrates, supply plants and the animals that eat plants with energy.

$$6H_2O + 6CO_2 + \text{radiant energy} \rightarrow C_6H_{12}O_6 + 6O_2 \quad (1)$$

Biomass is organic, carbon-based material that reacts with oxygen in combustion and natural metabolic processes to release heat having temperatures more than 400oC. This may be used to generate electricity.

## 1.2. History

In 1700s, biofuels were used as liquid fuels to generate light and warmth. The first biofuel plant was built in Brazil (1927). It was in 1975 when the name biomass was officially accepted and known. Biomass history has evolved a lot over the past decades and continues to improve until today..[10]

## 1.3. Sources and types of Biomass

Biomass originated from living and plant sources like: forestry products, plantation forestry, agricultural residues; wood; waste material from processing industries; commercial operations waste; food, used vegetable oil, tallow; industrial by-products; sugar, pulp and paper residues; municipal sources; construction and demolition, rotting garbage, and agricultural and human waste; energy crops; agricultural waste, rice husks, fruit pits and corncobs; animal husbandry residues, such as poultry litter, sewage sludge. Other sources are : aquatic, field, animal, oil seeds, firewood waste energy; alage; landfill gas and biogas; ethanol; biodiesel; bioenergy; commodity food crops; [7]; woody crops; genetically modified varieties and energy crops.

## 1.4. Energy Density

The heat energy available in combustion, equivalent in practice to the enthalpy or net energy density. eg. 8MJ/kg (un dried 'green' wood); 15MJ/kg (dry wood); 40MJ/kg (fats and oils); 56MJ/kg (methane).

## 1.5. Biomass Resources

- **World resources** : Total annual production of biomass is over 100 billion tonnes of carbon /yr,[7] . Energy reserve per tonne of biomass is between about 1.5×103 and 3×103 kilowatt hours or 24.8 TW average. Biomass could provide 1.4 times the approximate annual 150×103 terawatt-hours required for current world energy consumption.[7]
- **India resources** : India produces about 450-500 million tonnes of biomass per year. Biomass provides 32% of all the primary energy use in the country at present. Power from biomass in India varies from about 18,000 MW to a high of about 50,000 MW. Government plans to meet 20% of the country's diesel requirements by 2020 using biodiesel. Plants like Jatropha curcas, Neem, Mahua and other wild plants are identified as the potential sources for biodiesel production in India. There are about 63 million ha waste land in the country, out of which about 40 million ha area can be developed by undertaking plantations of Jatropha. India is the 7th largest country in the world spanning 328 million hectares and amply bestowed with renewable sources of energy. The current availability of biomass in India is estimated at about 500 millions metric tones per year. Surplus biomass availability at about 120 – 150 million metric tones per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. This apart, about 7000 MW additional power could be generated through bagasse based cogeneration in the country's 550 Sugar mills [11].

### 1.6. Biomass Charecteristics

Biomass consist of three main segments: wood, waste, and alcohol fuels (Figure 1).

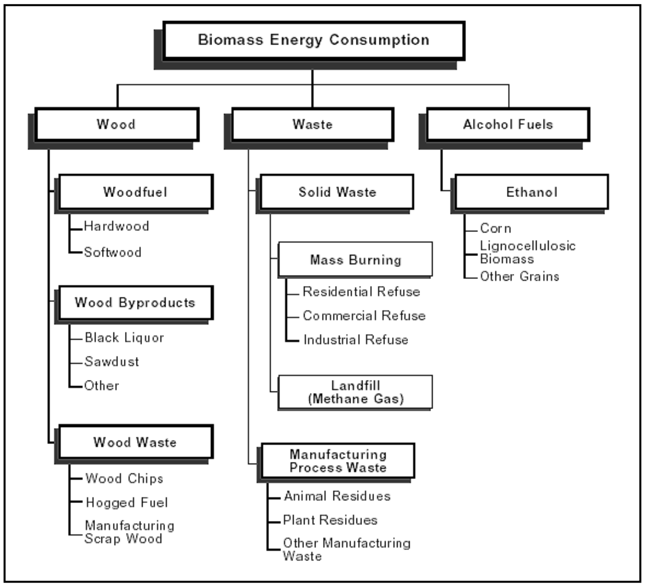


Fig. 1: Biomass Charecteristics.

## 2. Technology

Biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.

Bioenergy Conversion Processes includes Pretreatment (steam, torrefaction, pelletizing, densification); Fermentation (aerobic, anaerobic); SSF (enzymes, cellulase,); Anaerobic digestion (UASB, two stage, acidification); Thermochemical conversion ; Combustion (small scale, heating, cooking, travelling grate, CFB) ; Gasification (downdraft, fixed bed, BFB, CFB, SNG, gas cleaning, reforming); Pyrolysis (fast, slow, pyrolysis oil, char, biochar, charcoal, retort) and Liquefaction (hydrothermal, indirect).

Conversion of biomass to biofuel can be achieved by three different methods and nine general types which are broadly classified into: thermal, chemical, and biochemical methods.

### 2.1. Thermal Conversion

The thermo conversion of biomass to useful products involve combustion, gasification or pyrolysis. Biomass burnt in high pressure boiler to generate steam and operating a turbine with generated steam. Power cycle efficiencies that can be achieved are about 23-25%. Thorat Sahakri sakhar karkhana ltd sangamner maharastra is generationg 30 MW cogen power. Other thermal processes are hydrothermal upgrading (HTU), hydroprocessing, combined heat and power (CHP) and co-firing

### 2.2. Biochemical Conversion

Biochemical conversion makes use of the enzymes of bacteria and other microorganisms to break down biomass into gaseous or liquid fuels, such a biogas or bioethanol by conversion process: anaerobic digestion, fermentation, and composting. Thermostable variants are having key roles as catalysts in biorefining and produce chemical intermediates, oligocaccharide, surfactants like $alky_l$ glycoside type. Various biochemical conversions of biomass to useful energy product can be summarized as;

- **Aerobic digestion:** It generates heat with the emission of $CO_2$, but not methane. This process is of great significance for the biological carbon cycle, e.g. decay of forest litter.

- **Anaerobic digestion:** Certain microorganisms can obtain their own energy in the absence of free oxygen, by reacting with carbon compounds of medium, to produce both $CO_2$ and fully reduced carbon as $CH_4$. The process may also be called 'fermentation', but is usually called 'digestion'. The evolved mix of $CO_2$, $CH_4$ and trace gases is called biogas but may be named sewage gas or landfill-gas as appropriate. Four main stages or path way of anaerobic digestion are hydrolysis; acidification/acedogenesis; acetogenesis and dehydrogenation and methanogenesis .
- **Alcoholic fermentation:** It is manufactured by the action of micro-organisms on starchy materials and called fermentation process. Conventional fermentation has sugars as feedstock.
- **Biophotolysis :** Photolysis is the splitting of water into hydrogen and oxygen by the action of light. Certain biological organisms like microalgae and cyanobacteria produce, hydrogen in biophotolysis.
- **Photofermentation :** In this processes organic compounds, like acetic acid, are converted into hydrogen and $CO_2$ with sunlight by bacteria under anaerobic conditions. A large surface area is needed to collect light.

## 2.3. Agrochemical Conversion

Fuel extraction. Liquid or solid fuels may be obtained directly from living or freshly cut plants (exudates) by tapping the stems or trunks or by crushing freshly harvested material.

- **Biodiesel and esterification**: Concentrated vegetable oils from plants may be onverted to the corresponding ester, which is arguably a fuel better suited to diesel engines than conventional (petroleum-based) diesel oil. Vegetable oils are extracted from biomass like 1. Seeds: e.g. sunflower, rape, soya beans; 2. Nuts: e.g. oil palm, coconut copra; 3. Fruits: e.g. olive. 4. Leaves: e.g. eucalyptus 5. Tapped exudates: e.g. rubber latex; jojoba, Simmondsia chinensis tree oil. 6. By-products of harvested biomass, for example oils and solvents lke turpentine, rosin, oleoresins from pine trees, oil from Euphorbia. 7. Waste (used) cooking oil and from animal fat (tallow).
- **Biofuels:** Genetic engineering tools and synthetic biology techniques identify and alter relevant bioenergy genes and pathways in microbes for the production of high value products including novel biofuels. Some properties include high substrate utilization and processing capacities, fast growth rates and deregulated pathways for sugar transport, good tolerance to the biofuel product, high metabolic fluxes, and very importantly, ability to utilize cheap feedstock.
- **Biomethane**: Methane produced from biomass is referred to as Bio-Methane, Green Gas, Bio-Substitute Natural Gas (Bio-SNG) or Bio-CNG when it is used as a transport fuel. The processes are favoured by wet, warm and dark conditions. The reactions are slightly exothermic, heat of reaction being about 15MJ/kg dry digestible material, equal to about 250kJ per mole of $C_6H_{10}O_5$. This is 90% conversion efficiency. Yield rates doubling at about every 5C of increase.
- **Sequestration**: $CO_2$ sequestration includes the storage part of carbon capture and storage of industrially produced $CO_2$ using subsurface reservoirs, ocean water, aging oil fields, or other carbon sinks.
- **Bio-SNG:** Production of biomethane from the bio-chemical conversion of biomass (biogas) and via thermo-chemical conversion of solid biomass, so called Bio-SNG.
- **Raw biogas** Biogas can be produced out of any organic material under anaerobic conditions by ( 37 and 42°C (mesophiles) or 50 to 60°C (thermophiles). Composition of the biogas varies from 50 to 75 % methane ($CH_4$) and 25 to 45 % carbon dioxide ($CO_2$). Raw-biogas is saturated with water and contains different micronutrients; the most important is hydrogen-sulphide ($H_2S$).
- **Biomethane through gasification**: Gasfication temperatures are maintained between 500-1400°C. Different gasfication medium are: air, oxygen, steam or combinations depending on the final product wanted. Purification is done in three steps: Decarbonation, Desulfurization, Dehydration and Distribution

- **Hydrogen from biomass**: The conversion of biomass into hydrogen have higher energy conversion efficiency than for bio-methane. Hydrogen is the preferred energy carrier for electricity generation in low temperature in Proton Exchange Membrane (PEM) fuel cells. It reduce overall $CO_2$-emissions.
- **Biological hydrogen production by darkfermentation**: Hydrogen production by dark-fermentation is carried out by anaerobic bacteria, grown in the dark on carbohydrate-rich substrates. Dark-fermentation processes produce a mixed biogas containing primarily H2 and carbon dioxide ($CO_2$), but which may also contain lesser amounts of $CH_4$, CO, and/or hydrogen sulphide ($H_2S$).
- **The water-gas shift (WGS) reaction:** The reaction of carbon dioxide with steam to make more hydrogen is called the water gas shift reaction. Hydrogen must be separated from the shifted gas containing $CO_2$, CO, and other trace contaminants, and polished (cleaned further) to meet the requirements for various end-uses (e.g., fuel cell vehicles).

### 2.4. Chemical Conversion

Many of these processes like Fischer-Tropsch synthesis, methanol production, olefins (ethylene and propylene), and similar chemical or fuel feedstocks are producing biofuel. Other methods are biomass gasification; to produce producer gas. Biomass also has the potential to be converted to multiple commodity chemicals like Halomethanes,[8] S-adenosylmethionine, ethylene.

### 2.5. Electrochemical Conversion

Biomass/biofuels can be directly converted to electrical energy via electrochemical (electrocatalytic) oxidation of the material. This can be performed directly in a direct carbon fuel cell, direct liquid fuel cells such as direct ethanol fuel cell, a direct methanol fuel cell, a direct formic acid fuel cell, a L-ascorbic Acid Fuel Cell (vitamin C fuel cell), and a microbial fuel cell [9].

### 2.6. Role of Nano Technology in Biofuel

Structurally ordered nanoparticles can produce biofuel because of their tailored porosity and surface chemistry; high specific surface area; large pore volume; and high thermal, chemical, and mechanical stabilities. For example, ordered mesoporous catalytic solid (MCS) nanoparticles can be used as a heterogeneous catalyst to enable cleaner biodiesel production . They increase the fuel efficiency of diesel by approximately 5%.

## 3. Deployment

In india a total of approximately 500 biomass power and cogeneration projects aggregating to 4760 MW capacity have been installed for feeding power to the grid. In addition, around 30 biomass power projects aggregating to about 350 MW are under various stages of implementation. Around 70 Cogeneration projects are under implementation with surplus capacity aggregating to 800 MW. States which have taken leadership position in implementation of bagasse cogeneration projects are Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Uttar Pradesh. The leading States for biomass power projects are Andhra Pradesh, Chattisgarh, Maharashtra, Madhya Pradesh, Gujarat and Tamil Nadu.

India has necessary manufacturing base for critical control equipment like Boilers; Steam Turbines; Other Equipment ( harvesters, balers, briquetting equipment, handling and firing equipment, pollution control systems etc. ) for biomass energy generation. It has well suited promotional policies like (Central Financial Assistance, fiscal incentives, concessional import duty, excise duty, tax holiday for 10 years, bank loans of up to Rs 15 crore for biomass-based power generators) for Biomass power projects. In addition, State Electricity Regulatory Commissions have determined preferential tariffs and Renewable Purchase Standards (RPS). Indian Renewable Energy Development Agency (IREDA) provides loan for setting up biomass power and bagasse cogeneration projects. [11]

TABLE I: State-wise/year wise List of Commissioned Biomass Power /Cogeneration Projects (As on 01.04.2016)

| S.No. | State | Upto 31.03.2012 | 2012-13 | 2013-14 | 2014-15 | 2015-16 | Total(MW) |
|---|---|---|---|---|---|---|---|
| 1 | Andhra Pradesh | 363.25 | 17.5 | | | | **380.75** |
| 2 | Bihar | 15.5 | 27.92 | | | | **43.42** |
| 3 | Chattisgarh | 249.9 | | 15 | 15 | | **279.9** |
| 4 | Gujarat | 20.5 | 10 | 13.4 | 12.4 | | **56.3** |
| 5 | Haryana | 35.8 | 9.5 | | | | **45.3** |
| 6 | Karnataka | 441.18 | 50 | 112 | 111 | 158 | **872.18** |
| 7 | Madhya Pradesh | 8.5 | 7.5 | 10 | 9 | | **35** |
| 8 | Maharashtra | 603.7 | 151.2 | 185.5 | 184 | 96.38 | **1220.78** |
| 9 | Odisha | 20 | | | | | **20** |
| 10 | Punjab | 90.5 | 34 | 16 | 15 | | **155.5** |
| 11 | Rajasthan | 83.3 | 10 | 8 | 7 | | **108.3** |
| 12 | Tamil Nadu | 532.7 | 6 | 32.6 | 31.6 | 39 | **626.9** |
| 13 | Uttarakhand | 10 | | 20 | 20 | 13 | **50** |
| 14 | Uttar Pradesh | 644.5 | 132 | | | 93.5 | **842** |
| 15 | West Bengal | 16 | 10 | | | | **26** |
| | **Total** | **3135.33** | 465.6 | 412.5 | 405 | 400 | **4831.33** |

## 4. Impact

Various impacts of biomass projects have several impacts: like Social and environmental aspects; Environmental damage; and Supply chain issues. There are several potential challenges unique to bioenergy supply chains, like: Technical issues, Logistic issues, Financial issues; Social issues; ; Policy and regulatory issues; Institutional and organizational issues.

## 5. Bioenergy Utilization

Depending on the process of manufacturing bioenergy can be used in direct combustion engines (steam cycle, hot oil, kiln, furnace); Co-firing (coal, natural gas) and CHP . Gasification used in (kilns, syngas, producer gas); Electricity Production (fuel cell, gas turbine, steam, carnot cycle, brayton cycle, Stirling) ; Chemicals (platform chemicals, intermediates, polymers) ; Biofuels; By-product remediation.

## 6. Advantage

Biomass used as a fuel reduces need for fossil fuels for the production of heat, steam, and electricity. The use of waste materials reduce landfill disposal and makes more space for everything else. It’s carbon neutral. It’s cheaper compared to fossil fuels. It minimizes overdependence on traditional electricity. It can be used to create different products:

## 7. Disadvantage

Disturbing agricultural wastes. Biomass conversion projects from animal wastes are relatively small and therefore are limited. It increases methane gases, which are also harmful to the Earth’s ozone layer. Uncontrolled biomass production can result in deforestation. It requires a great deal of water. It doesn’t get close to fossil fuels in regards to efficiency. In fact, some renewable sources of energy like biofuels are fortified with fossil fuels to increase their efficiency.

## 8. Conclusion

Biomass power generation in India is an industry that attracts investments of over Rs. 600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in the rural areas. Different biomass materials used for power generation include bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, de-oiled cakes, coffee waste, jute wastes, and groundnut shells, saw dust etc.

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